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A new optimization CAD/CAM/CAE technique for the processing of the complex 3D surfaces on 5 axes CNC machines

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Abstract

In the case of complex surfaces, the processing on 5 axes CNC machines may be approached by taking into consideration the fact that the axis of the cutting tool must stand in a normal direction towards the plan of the surface that needs processing. In this case, a data file will be used, which will be transferred to an application which is capable of generating the CNC code that can be recognized by the programming language of the machine. At the same time, in order to optimize this procedure, the processing of the 3D solid surfaces may be approached. In this case, the piece which is considered a solid, may be decomposed into successive sections that will optimally be processed on the 5 axes CNC machine using the facilities of the 5 axes CNC machine.
One viable solution that can be applied in the case of the processing of the 3D surfaces is the decomposition of a solid into successive sections, according to the processing plan. If we use the procedure above described for the processing of the 3D complex surfaces, essential benefits will occur, related to the conditions of the processing, using a cutting tool on a 5 axes CNC machine, especially as compared to the 3 axes CNC machine. In the case of the processing procedure of a 3D complex surface held on a 3 axes CNC machine, risks may appear, such as obtaining a surface with form errors caused by inappropriate position of the cutting tool towards the generated outline. This inconvenient may be eliminated when using a 5 axes CNC machine. This procedure is the subject of the study presented in this article.

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Keywords: 3D complex surface; CNC machines; processing with the cutting tool; CNC code; the position of the cutting tool.

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1. Introduction

The research has been firstly made through a simulation of the sectioning of a piece in 3D complex surface and through designing an AUTOLISP application, which is an AUTOCAD component, in order to generate the trajectory of the cutting tool according to the control points in the drawing upon which the processed piece is being complete. With the help of the AUTOLISP application, we can obtain an efficient use of the 5 axes CNC machine, hereby commanding both B and C axes for the optimal placement of the cutting tool towards the movement direction on the desired outline. As a result of the application of this tridimensional processing technique on a 5 axes CNC machine, a piece will be obtained, with the geometric precision situated in between the tolerance field, according to the requirements of the beneficiary. The quality of the surface will also be high and the durability of the cutting tool will grow, as a result of its maintaining in the optimal processing position all through the processing.

The normal position of the cutting tool at the surface that needs processing may be ensured through mathematical calculations when generating the CNC code for the 5 axes processing.

In the case of the processing on a 3 axes CNC machine, the generated profile will be defined with the coordinates X Y Z as compared to the 5 axes processing, where the command code will be extended to the positioning of the B and C axes. The obtaining of the CNC code will be ensured by a POSTPROCESSOR application.

```
(defun C:Extbc ()
      (setq fis (getstring "\nfile name:")
          fp (open fis "w")
     )
      (if (setq f (open "c:/cnc/proba.txt" "r"))
        (progn
          (while
                (setq pt1i (read-line f))
                (setq pt1 (read (eval pt1i)))
                (setq pt2i (read-line f))
                (setq pt2 (read (eval pt2i)))
            (setq x1 (nth 0 pt1))
                (setq y1 (nth 1 pt1))
                (setq z1 (nth 2 pt1))
                (setq x2 (nth 0 pt2))
                (setq y2 (nth 1 pt2))
                (setq z2 (nth 2 pt2))
                (setq b1 (atan (/ (- z1 z2) (sqrt (+ (* (- x1 x2) (- x1 x2))  (* (- y1 y2) (- y1 y2)))))))
                (setq c1 (atan (/ (- y1 y2) (- x1 x2))))
                (setq b (- 90 (/ (* b1 180.) pi)))
                (setq c (/ (* c1 180.) pi))
                (princ "G1 X" fp)
                (princ x1 fp)
                (princ " Y" fp)
                (princ y1 fp)
                (princ " Z" fp)
                (princ z1 fp)
                (princ " B" fp)
                (princ b fp)
                (princ " C" fp)
                (princ c fp)
                (princ "\n" fp)
          )
          (close f)
        )
```

```
  (princ "\n Error - File was not opened.")
)
```

2. Case study

CNC manufacturing has evolved from the automated machine tools of the 1960s to the modern multi-process multi-axis machining centers [1]. CNC machines tools are the main components in any manufacturing system [2]. There are demands and new opportunities to empower the current CNC machines with the much-needed features such as interoperability, adaptability and agility [2]. Modification of one factor may have significant consequences on the productivity, on the quality and may cause some faults in the process [3].

Because of the high demand of maximum productivity in the CNC machining, the time optimal trajectory generation process plays an important role in motion planning problem [7].

In the presented case we have studied the possibility of introducing the CAM/CAD/CAE methods for a complex profile related to the Cam-operated clamp presented in the Fig.1.The piece has been realized for the study of the complex profiles processing, with the purpose of reducing the processing time and optimizing the costs related to cutting tools.

Fig.1. Cam-operated clamp

In the execution drawing, both the Cam-operated clamp and the thread profiles are defined. In this case, the thread is metric 22x1.5. The clamping force for the spooling operation is relatively low therefore the metric thread can be used. This thread is widespread and relatively easy to process on any CNC or conventional machine.

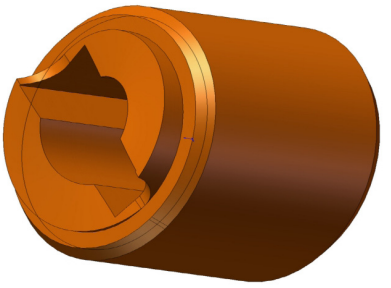

Fig.2. Frontal profile of the Cam-operated clamp

3. Processing the Cam-operated clamp profile

Over the years, computer numerical control (CNC) machine tools have developed, with the ability to machine high-precision products [6]. This profile can be processes on a MAZAK QTN 250 M lathe with three tools trained into three axes for a large area of profiles with small outline sizes. In this case, there can be used a milling machine.

The profile of the Cam-operated clamp has been produced with the help of a finger mill FI 6. The profile of the thread has been processed with a threading knife SECO with tiles 16ER 1.5ISO and covering CP500. The purpose of this study is finding a method through which 3D complex surfaces can be processed. The study focuses on Cam-operated clamps for large outline profiles, which cannot be processed on 3 axes machines MAZAK QTN 250 M. For the small manufacturing enterprise, individual machining workstations will no longer have to be dedicated to specific jobs/components [5]. Another goal of the study, with the same importance, is the management of the cutting tools we have proposed to use a reduced number of tools in order to obtain high complexity profiles.

4. Processing the threads on CNC machines

Because of the diversity of thread profiles that need to be processed, in order to ensure the wanted clamping force, new splinting technologies will be used. First of all, we must take into consideration the geometrical parameters of the profile in order to select the proper cutting tool. According to the geometrical parameters of the profile and the size of the gauge we choose the CNC machine that produces the profile of the thread.

If we choose a four axes CNC machine with a horizontal pivot of BOHRWERK type, we must center the Cam-operated clamp in the middle of the operating machine, which is rather difficult to accomplish.

In order to eliminate the positioning errors for the operation of centering the processing piece, we used a five axes CNC machine ZAYER KP 6000 AR which has a digital device for processing the fixed point, in this case, the center of the cam. Therefore, the time used for centering the piece is eliminated and the preparatory operations remain to be the fastening of the piece in a certain position on the machine. The only condition that is requested is to have access to the processing profile from any position.

In Fig.4, there is the five axes CNC machine ZAYER KP 6000AR, also called portal milling machine that we have used in order to obtain the wanted profile of the thread.

The dimensions of the throws 6000 X 3500 X 1100 (X, Y, Z)

The portal milling machine KP 6000 AR produced by ZAYER is composed of: Longitudinal cheek, Crossbeam, Vertical sled, Processing head, Operating panel.

The longitudinal cheek passes through the two vertical columns and across the grips of the cheek. The machine moves towards axis X. the crossbeam is placed on the two vertical columns along the grips of the transversal barrow and moves towards axis Y. The vertical sled has the grips on the transversal barrow and represents axis Z.

The machine is tooled with two processing heads: Vertical immovable, Circular head.

With the help of the immovable processing head the machine is able to work on three axes only, X, Y, Z, but it offers a high stability to the machine. In the case of the circular processing head, the rotation movement around axes Y and Z is allowed. These axes are called B and C.

In Fig.3 it is shown the head of the frontal mill. Because of the diversity of the movements of the portal milling machine, the manufacturing process of the thread is improved, no matter of the complex geometry of the profile. The kinematics of the five axes machine will allow the covering of any layout of the cutting tool which generates the wanted profile, eliminating the supplementary positioning movements of the tool during the manufacturing process.

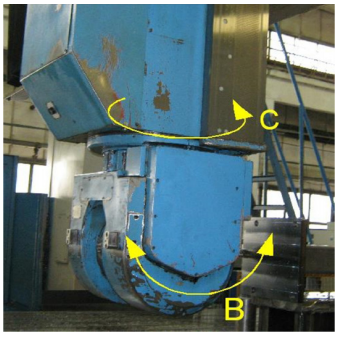

Fig.3. The processing head of the portal milling machine

The trapezoidal threaded Cam-operated clamp from Fig.4 has been processed on a portal milling machine KP 6000 AR because of the facilities related to the kinematics of the machine and of the programming language TNC 426-430.

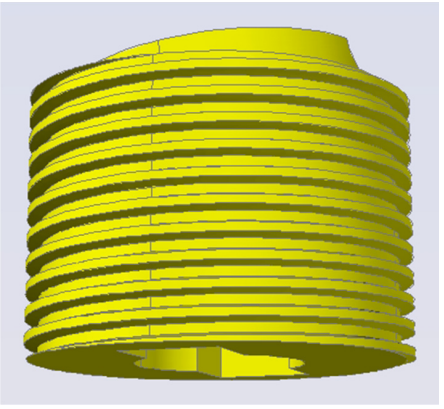

Fig.4.The trapezoidal threaded Cam-operated clamp

In Fig.5 and Fig.6 we have presented the positioning of the machine head in two stages of the manufacturing process of the trapezoidal thread.

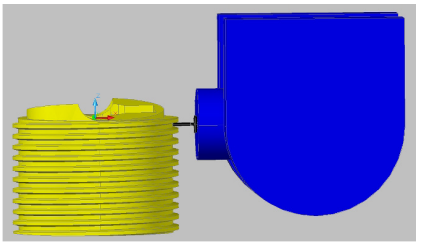

Fig.5. Machine head in working position on the surface described by the interior diameter of the trapezoidal thread

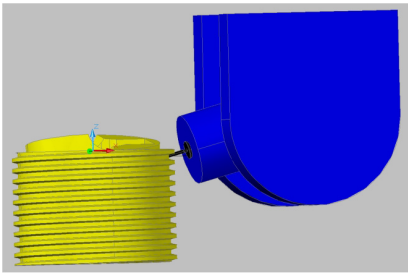

Fig.6. Machine head in working position on the flank of the trapezoidal thread

The programming language is TNC 426-430, developed by HEIDENHAIN Company. HEIDENHAIN TNC CONTROLS has as a purpose the programming in conventional languages and is built especially for milling, cutting

and reaming operations on CNC machines. The objective of turning and milling process is to assure relative motion of the tool with respect to the work piece [3].

Hereby, TNC 426C may control the manufacturing on machines with up to five axes, while TNC 430 may control up to nine axes. The positioning of the axes system may also be changed. An integrated hard disk ensures the storage of the programmes, even if they have been created off-line. These sequences of program may be included in the subsequent created programs. For fast calculations, the calculator from the command panel may be used, without fear of affecting the manufacturing process. The keyboard and the display are placed in such a way so as their functions to be accessed rapidly and easily. The programming language TNC 426-430, developed by HEIDENHAIN Company is a method of writing programs in standard languages ISO. The graphical interface allows you to follow step by step the stages of the programming. If an execution drawing is not NC compatible, HEIDENHAIN FK automatically realizes the necessary calculations for trace of the desired outline.

The manufacturing of the pieces may be graphically simulated both before the beginning of the process, and during its development. Another facility of TNC programming is the possibility of testing a program sequence during the execution of another process.

5. Conclusions

As a result of the study developed on five axes KP 6000 AR CNC machine we have concluded that, through this procedure, we are able to process trapezoidal threads of big sizes using a minimum number of tool positioning, offered by the liberty degrees of the machine head. In this case, the use of a shell mill is the solution to obtain the profile of the thread from three successive positions, working on the same CNC program. There is also the possibility of manufacturing threads with different angles of flank leaning. The geometry of the thread will be realized through the proper leaning of the machine head.

References

[1] Newman ST, Nassehi A. Universal Manufacturing Platform for CNC Machining; Annals of the CIRP Vol. 56/1/2007;p.459-462.
[2] X.W.XU, Newman S.T. Making CNC machine tools more open, interoperable and intelligent-a review of the technologies, Computers in Industry 2006; 57:141-152.
[3] Kovacic M.,Brezocnik M., Pahole I., Balic J., Kecelj B. Evolutionary programming of CNC machines, Journal of Materials Technology; 2005; p.164-165; p.1379-1387.
[4] Yih-fong T, Ming-der J. Dimensional quality optimisation of high-speed CNC milling process with dynamic quality characteristic; Robotics and Computer-Integrated Manufacturing 21 (2005); p. 506-517.
[5] Newman ST, Nassehi A, Xu XW, Rosso Jr. RSU, Wang L, Yusof Y, Ali L, Liu R, Zheng LY, Kumar S, Vichare P, Dhokia V. Strategic advantages of interoperability for global manufacturing using CNC technology, Robotics and Computer-Integrated Manufacturing 2008; 24: 699-708.
[6] Ridman S, Xu X, Advanced CNC system with in-process feed-rate optimization, Robotics and Computer-Integrated Manufacturing 2013; 29:12-20.
[7] Zhang Qiang, Li Shurong, Guo Jianxin, Smooth time-optimal tool trajectory generation for CNC manufacturing systems, Journal of Manufacturing Systems 31 (2012), p. 280-287.